

AN OPERATIONS RESEARCH MODEL OF A HEALTH
CARE APPOINTMENT SYSTEM

Robert Stanley Nemmers

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AN OPERATIONS RESEARCH MODEL
OF A HEALTH CARE APPOINTMENT SYSTEM

by

Robert Stanley Nemmers

September 1975

Thesis Advisor:

R. W. Butterworth

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An Operations Research Model
of a Health Care Appointment System

by

Robert Stanley Nemmers
Lieutenant Commander, Supply Corps
United States Navy
B.S., North Carolina State University, 1963

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This study models a clinic at Silas B. Hays Hospital, Fort Ord, California. The purpose is to propose a means of scheduling appointments in a clinic. Estimates of parameters of the model were made, inputs and outputs of the model were calculated and a sensitivity analysis was performed. Finally, conclusions were stated.

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I. INTRODUCTION

The hospital at Fort Ord provides inpatient and outpatient health care services to active and retired military personnel and their dependents residing in Monterey and adjoining counties. Health care services are also provided to transient military personnel. The primary health care delivery facility is the hospital on the Fort Ord Post. A number of satellite facilities, such as the Family Practice Clinic, Optometry, and Troop Medical Clinics treat patients or refer them to the hospital.

The Obstetrics-Gynecology (OB-GYN) Clinic located in the hospital is the subject of this research effort. The purpose is to prescribe an appointment system for clinics in general using the OB-GYN Clinic as an example. The clinic is staffed with military and civilian personnel. The staff consists of about 18 personnel including six doctors. The number of doctors, nurses, medical assistants, and receptionists varies due to personnel turnover and workload. In general the efforts of the staff are concentrated in the clinic providing services to outpatients. However, the military doctors are also responsible for inpatient care including, surgery,

training and other administrative and military duties, all performed outside the clinic.

The OB-GYN Clinic has an average of 2233 patient encounters per month. Services involve one, some, or all of consultation, examination, medical procedures, injections, lab procedures, therapy and prescription of drugs and medicines. Patients are seen by appointment or on a walk-in basis when an emergency exists. Appointments are made by a satellite facility on the patients' behalf. The times allotted for appointments are 10, 15, or 20 minutes. The typical encounter between patient and doctor lasts about 17 minutes. The shortest encounters last only a few minutes, the longest may exceed an hour.

The physical layout of the clinic includes a reception desk and waiting room, six doctor's offices, 12 examination rooms, two medical supply and equipment rooms, lavatory and toilet facilities, and various administrative and staff offices. Each examination room is completely equipped. Typically, each doctor uses two examination rooms treating one patient while another is being prepared for treatment in the other examination room.

The clinic observes an eight-hour-a-day, five day work week Monday through Friday. Outside of normal operating hours, patients are treated in the Acute Minor

Illness Clinic or the Emergency Room. Patients are given appointments between 8:00 and 11:10 AM and between 1:00 and 3:30 PM with minor adjustments depending on the day. To the extent practicable, all patients requiring the same type of service or treatment are appointed to be seen during a common block of appointments. Thus the clinic specializes its services wherever possible.

II. DATA COLLECTION

A. METHOD OF COLLECTION

The data collection sheet was designed with sufficient instructions to permit the patient to fill it out if necessary. It included social security numbers to permit the clinic to substitute the data sheet for its sign-in roster if desirable. The data sheet indicated military status, service affiliation and sponsors' affiliation for dependents. If the patient had an appointment, the time was indicated. The most frequently demanded treatments were available to be checked. The reception desk staff was instructed to fill in a specific treatment by "other" for less frequently demanded treatments or procedures. The time of entry and departure from the clinic was applied to the sign-in sheet by the reception desk personnel with a time stamp. The times of entry or exit from the examination room and/or doctor's office were applied by the patient's escort. Each sign-in sheet was numbered to assure knowledge of sheets lost or removed from the clinic. This, combined with a record of cancellations and patients who did not show up for appointments, permitted an accurate estimate of the outpatients treated in the clinic.

Three SIMPLEX electric date-time machines were positioned at convenient locations in the clinic. One was positioned at the reception desk and one in each of two hallways outside of the examination rooms and doctor's offices. The date-time stamp included the year, month, day, AM or PM, hour, and minute. The time was incremented one minute each 60 seconds. Therefore, the recorded elapsed time the patient spent with the doctor could be at most a minute off. The clocks were synchronized each morning to the minute but could not be synchronized to the second. .

As each patient checked in at the reception desk, the receptionist initiated the sign-in sheet by filling in all appropriate information and stamping the time of arrival in the clinic. The sheet was then inserted into the patient's health record which accompanied the patient to the examination room and/or doctor's office. Depending on the type of treatment the patient might start in an office, enter an examination room, and end in the doctor's office. Most patients, however, start in an examination room and end in an office. Some visit only an examination room or doctor's office but not both. In all cases, the total time spent with the doctor is calculated by adding time spend in the examination room and in the doctor's office. As the patient entered and departed the examination room or

or doctor's office the escort inserted the sign-in sheet into the date-time machine. Upon completion of the treatment, the escort or patient returned the health record and sign-in sheet to the reception desk where the clinic departure time was stamped and the sheet retained.

Data was collected in the clinic from Friday 2 May 1975 through Friday 16 May 1975. The clinic was open approximately eight hours a day Monday through Friday. The period 2-16 May included 11 of the 21 working days of the month.

During the data collection period a total of 1404 sign-in sheets were used generated by approximately 1118 doctor-patient encounters, 126 prescription refills, and 51 obstetric-class students. A total of 27 sheets were lost, the remaining were voided due to missing data fields. After the data was placed on IBM cards, the cards were verified to the extent that all data fields appeared in the correct card columns. Obvious misspunches and evident omitted and transposed characters were corrected. A card by card validation against original data was not accomplished but a spot check was performed to insure the program accurately calculated service time and time in system.

Data sheets indicated that approximately 18 distinguishable treatments were being performed in the clinic.

These were aggregated into five treatment groups to correspond to the differentiation used by clinic personnel.

B. IDENTIFICATION OF TYPE OF SERVICE OR TASK

A wide variety of treatments and medical services were offered in the clinic. The broadest differentiation classified a visit as obstetric or gynecological in nature. Within each of these there are many subgroups which can be differentiated by experience level, instruments, and average time required for the treatment. Each of these treatments have distinctive clinical names many of which may be unknown by a patient. Complaints and descriptions of problems by patients tend to be general and not very specific. Consequently, identification of type of service to be performed was reduced for ease of scheduling appointments, to five groups. There are two types of obstetric visits. They are identified as "Initial OB" and "Follow-up OB". There are three types of gynecological visits. They are identified as "Gynecology", "Pap and Pill", and "Postpartum-Post Operative". In this study these treatments are identified as "1", "2", "3", "4", and "5" respectively. To achieve efficiency, patients with the same complaint are given appointments for the same morning or afternoon of a workday according to the following schedule.

Monday	AM	GYN Clinic (3)
	PM	Prenatal (OB Follow-up) Clinic (2)
Tuesday	AM	Various
	PM	GYN Clinic (3)
Wednesday	AM	Prenatal (Initial-OB) Clinic (1)
	PM	Pap and Pill Clinic (4)
Thursday	AM	Postpartum & Post Operative Clinic (5)
	PM	GYN Clinic (3)
Friday	AM	Prenatal (OB Follow-up) Clinic (2)
	PM	GYN Clinic (3)

Patients with emergencies are seen any day or time with or without an appointment in the Clinic during its normal operating hours or in the Emergency Room after hours and on holidays.

C. RESULTS OF DATA COLLECTION

Tables 1, 2, and 3 provide statistics concerning data collected, distribution of encounters, and appointment efficiency.

TABLE 1
DATA SHEET ACCOUNTING

<u>Status of Data Sheets</u>	<u>Number</u>	<u>Percent</u>
Usable Data	1295	92.5
Voided	66	4.7
Lost or Destroyed	43	3.1
Total	1404	100.0

TABLE 2
DISTRIBUTION OF ENCOUNTERS

Encounter Type	Number	Percent
Appointments	1000	77.2
Walk-ins	118	9.2
active military	41	
all others	77	
*Prescription Refills	126	9.7
**Prenatal Class (New OB Class)	51	3.9
Total	1295	100.0

*Requires doctor's signature only

**Taught one morning per week by Nurse Clinician

TABLE 3
APPOINTMENT EFFICIENCY

Description	Number	Percent
Appointments Made	1156	100.0
Cancellations	(53)	(4.6)
No-Shows	(103)	(8.9)
Appointment Encounters	1000	96.5

TABLE 4
STATUS OF PATIENTS AS PERCENT
OF ALL ENCOUNTERS

Status	Number	Percent
Active Military	180	16.1
Dependents of Active Military	771	69.0
Retired and Dependents of Retired and Deceased Military	<u>167</u>	<u>14.9</u>
Total	1118	100.0

Table 4 indicates the status of the patients treated during the study.

TABLE 5
ARRIVALS

Category	No.	Percent	μ	σ	Range
Early	566	56.6	16.8	16.3	1.0- 96.0
On Time	41	4.1	0	0	0
Late	<u>393</u>	<u>39.3</u>	11.9	14.0	1.0-105.0
Total	1000	100.0			

Tables 5 and 6 provide statistics concerning arrivals. Values are mean times in minutes.

TABLE 6

PATIENT DELAY AND TIME IN SYSTEM

<u>Patient Category</u>	<u>μDelay</u>	<u>σ</u>	<u>μTime In Sys.</u>	<u>σ</u>
Appointments	32.5	19.5	51.8	22.7
No Appointment	30.4	27.4	53.1	32.1

Of 1146 patient-doctor encounters 28 or 2.4 percent had encounter times greater than 50 minutes. The average was 66.4 minutes and the range was 50 to 103 minutes. These encounters were considered outliers and were not included in calculating the overall clinic average service time or the average service time for a type of service. It was likely during these long encounters the doctor left the patient for periods of time to treat other patients or to do other work.

The clinic physician staff during the study period consisted of five military OB-GYN specialists, one civilian OB-GYN specialist and up to three residents. In addition one Nurse Clinician also performed OB examinations, conducted prenatal classes for new obstetrics patients and provided other routine treatments and services to patients. Frequently one or two doctors fulfilling their residency requirements were in the clinic to learn from the specialists and to assist with the patients. The average number of hours spent

in the clinic per day by military specialist, civilian specialist, resident and the Nurse Clinician were 5.2, 7.4, 4.5, and 6.8 hours respectively.

The clinic provided a wide range of services and treatments. The work week was segmented into ten clinics, five morning and five afternoon. All patients requiring the same type of service were scheduled for the same morning or afternoon.

Table 7 indicates scheduled and actual treatment or service times in minutes by group (OB or GYN) and by type of treatment within group.

TABLE 7
ENCOUNTER OR SERVICE TIMES

	OB			GYN	
	1	2	3	4	5
Appointment Time Scheduled	20	10	20	15	20
Actual Average Service Time(min)	17.1	13.3	19.6	16.7	16.6
Cummulative Averages(min)	13.8			18.6	

The average service time for all patients over all days was 16.6 minutes. Of the demands for service, 42 percent were for OB treatments and 58 percent were for GYN treatments.

The variance observed in encounter or service time may be attributed to characteristics of patients, doctors, day and time, and severity of condition to name a few of the possible causes. For example, due to emotional state, or lack of knowledge a patient may have difficulty in providing details concerning her condition. The complaint may be expressed haltingly or in very general terms requiring the physician to ask many questions. If the problem is emotional in nature, the consultation part of the treatment may include an opportunity for the patient to express fears and vent feelings. The experience level of the physician caused different service rate among the physicians. If the complaint was different from those normally seen during that appointment period, additional time might be required to assemble materials, medicines, and equipment.

In general, as severity of the complaint or condition increases, the greater the encounter time required. Severe conditions may require consultation among several members of the medical staff in the clinic.

In addition to consultations, a physician may be interrupted to answer the phone, perform some administrative function, or might be called away from the clinic to treat an in-patient in surgery or on a ward.

No distinction was made concerning the performances of Nurse Clinicians. The data collection did not

capture physician to physician variation nor did it distinguish between physicians or nurse clinicians. Throughout the study the term physician, doctor, or medical personnel should be interpreted to include nurse clinicians.

Appointments are allocated as indicated in Table 8. During the study one civilian, seven military specialists, one nurse clinician, and three resident physicians provided medical services to patients. The civilian specialist worked exclusively in the clinic, the military specialists treated inpatients and outpatients, the nurse clinician treated outpatients, and the resident physicians assisted the specialists in all of their duties but on a part-time basis during five of the eleven days of the study. The cumulative time spent in the clinic by all physicians was equivalent to the full-time services of approximately 6.7 physicians. Endowment of physician time to the clinic will be expressed in terms of full-time-equivalent (FTE) physicians, that is weekly manhours of a physicians time equal to the number of hours the clinic remains open in a week.

The types of treatment demanded on any day may vary considerably from the planned appointments. The unplanned encounters represent those patients whose condition dictates an appointment outside the normal clinic schedule, or simply a failure of the clinic to insist on these hours.

TABLE 8
PLANNED APPOINTMENTS
PER FTE DOCTOR

Day	Type of Treatment					Total
	1	2	3	4	5	
Monday		16	10			26
Tuesday		1	13			14
Wednesday	9			9		18
Thursday			8		7	15
Friday		20	8			28
Total	9	37	39	9	7	101

TABLE 9
AVERAGE NUMBER OF ENCOUNTERS
BY DAY AND TYPE OF TREATMENT

Day	Type of Treatment					Total
	1	2	3	4	5	
Monday	3	70	45.5	8.5	2	129
Tuesday		2.5	49	6.5	2	60
Wednesday	16	5	16.5	52.5	.5	90.5
Thursday		1.5	54.5	8	20.5	84.5
Friday	9	86.3	36	5.7	1.3	138.3
Total	28	165.3	201.5	81.2	26.3	502.3

Table 9 indicates the average number of encounters by day and type of treatment. Dividing the numbers of

encounters by type of treatment by the number of FTE physicians generates the information of Table 10.

TABLE 10
AVERAGE NUMBER OF ENCOUNTERS
PER WEEK

Number of FTE Physicians	Type of Treatment					Total
	1	2	3	4	5	
6.7	28	165.3	201.5	81.2	26.3	502.3
1	4.2	24.7	30.1	12.1	3.9	75

A comparison of Tables 8 and 10 demonstrates a type of efficiency loss. Each FTE physician treats an average of 75 of a planned 101 appointments. A measure of clinic efficiency is the ratio of average actual encounters to planned appointments per FTE physician. Efficiency is therefore equal to 75 divided by 101 or 74.3 percent.

Possible causes of the loss in this type of efficiency are patient cancellations, no-shows, walk-ins, and late arrival of patients or physicians. Some loss of efficiency might be attributed to the difference in percent of appointments allocated to a treatment and the actual percent of encounters for that treatment. Table 11 displays those differences. Reductions in this loss could be achieved by tighter control on the appointment process, penalties to patients who are no-shows,

or over-scheduling to anticipate cancellations and no-shows.

TABLE 11
APPOINTMENT - ENCOUNTER COMPARISON

Treatment	1	2	3	4	5	Total
Current Appointments						
Number	9	37	39	9	7	101
Percent	8.9	36.6	38.6	8.9	7.0	100
Encounters						
Number	28	165	202	81	26	502
Percent	5.6	32.9	40.1	16.2	5.2	100
Suggested Appointments						
Number	6	33	41	16	5	101
Percent	5.9	32.8	40.6	15.8	4.9	100

In Table 11 appointments or encounters are per week. Current and suggested appointments are for one FTE physician. Encounters per week were generated by approximately 6 FTE physicians. The significant comparison is among the percents of each type of treatment.

The suggested number of appointments recognizes the disparity of the current appointment schedule to current encounters.

III. DESCRIPTION OF THE MODEL

Two cases or approaches will be examined. First the number of FTE physicians will be assumed known and fixed and the number of patients whose demands are provided for are calculated. Second, the number of patients whose demands are to be met will be known and the number of FTE physicians necessary to provide health care services will be determined.

Parameters in the model assigned values based on clinic policy or data are as follows:

A = Number of appointments per week that can be scheduled by the clinic.

a_i = Fraction of appointments A scheduled for treatment i .

C = The number of minutes per week the clinic provides services to patients.

c_i = Fraction of clinic time allocated for treatment i .

D = Mean number of demands per person per year for all treatments.

d_i = Mean number of demands per person per year for treatment i .

t_i = Scheduled service time for treatment i .

P = Full-time-equivalent (FTE) physicians.

Variables of the model are as follows:

E = Number of patient-physician encounters in the clinic per week.

N = Number of patients in the hospital service area who generate demands for service.

s = Scheduling efficiency factor.

$\hat{t}$ = Clinic average service time for all services or treatments.

Values of some variables are taken from data or derived from data. The model treats all quantities in a deterministic fashion. It is assumed that the fraction of all appointments a_i represents the long run proportion of demands for treatment i by patients. Thus, services are provided in the same proportions as demanded. Based on the data collection described earlier, these fractions are estimated, and the estimated values used in the model. It is also assumed that a sufficient number of patients desiring service are always available to make appointments.

Each patient in the hospital service area makes several demands per year on the hospital for services. The mean number of demands per patient per year (D) can be expressed as a function of age, sex, and the service being sought. We will rely on the data collected in this study for such a breakdown, and estimates of an overall demand rate (D) will be from the following Table.

TABLE 12⁽¹⁾HEALTH SERVICE UNIT DEMAND PER
PERSON PER YEAR

Sex Age	Male			Female		
	0-19	20-54	54	0-19	20-54	54
Number of Physician Visits/yr	3.9	3.4	5.5	3.7	5.2	5.9

It should be noted however, the data of Table 13 was collected in 1967, in a different part of the country, from a group with different health care coverage, and was generated by a population that may vary widely in an ethnic, socio-economic, and cultural, sense from the "military population" that existed at the time of this study.

A. PATIENTS DEMANDS TO BE SATISFIED, PHYSICIAN RESOURCES
FIXED

The number of minutes per week (C) the clinic provides medical services to patients and the planned length of appointments (t_i) are established by policy. Under the assumption that the fraction of encounters for treatment i is representative of true demand, mean

¹ Zemach, Rita, A Model of Health Care Utilization and Resource Allocation, p. 1079, Operations Research V:18, p. 1079, November-December 1970.

demand in units per patient per year for treatment i is expressed by equation 1.

$$d_i = D \cdot a_i \quad (1)$$

The portion of clinic time per week consumed in treatment i is the product of encounters and service time per visit ($a_i \cdot t_i$). The value for c_i is the fraction of time C for treatment i and is calculated as indicated by equation 2.

$$c_i = \frac{a_i \cdot t_i}{\sum_{j=1}^n a_j \cdot t_j} \quad (2)$$

The total number of appointments per week for treatment i is expressed by equation 3.

$$A_i = \frac{P \cdot c \cdot C}{t_i} \quad (3)$$

Substituting 2 into 3 yields equation 4.

$$A_i = P \cdot C \frac{a_i}{\sum_{j=1}^n a_j \cdot t_j} \quad (4)$$

For all types of treatment 4 yields:

$$A = \frac{P \cdot C}{\sum_{j=1}^n a_j \cdot t_i}$$

To recognize the existence of the clinic or scheduling inefficiency the expression for encounters includes, the scheduling efficiency.

$$E = \frac{s \cdot P \cdot C}{\sum_{j=1}^n a_j \cdot t_j} \quad (5)$$

Equation 5 indicates that at best the number of patient-physician encounters will equal number of appointments, but is usually less.

Assuming the demand rate D visits per patient per week, it follows that the number of patients, N , that can be supported by the clinic is:

$$N = E/D = \frac{s \cdot P \cdot C}{D \sum_{j=1}^n a_j \cdot t_j} = \frac{s \cdot P \cdot C}{D \cdot \hat{t}} \quad (6)$$

Where the expression $\sum_{j=1}^n a_j \cdot t_j = \hat{t}$ is a clinic average

service time over all treatments.

B. REQUIRED NUMBER OF FTE PHYSICIANS

The input in this case is the number of patients whose demands are to be met and the output is the number of FTE physicians required to treat the patients.

Each patient demands treatment i with a frequency of d_i . The treatment is given in t_i minutes. Therefore the demands of one patient for treatment i consumes $d_i \cdot t_i$ minutes per week. The patients demands for all services i

per week is $\sum_{i=1}^n d_i \cdot t_i$ minutes. If there are N patients, they generate a total requirement of

$N \cdot \sum_{i=1}^n (d_i \cdot t_i)$ minutes per week. One FTE physician endows the clinic with C minutes per week of which only $s \cdot C$ are used. Therefore, the equation for required number of FTE physicians :

$$P = \frac{N \sum_{j=1}^n d_j \cdot t_j}{s \cdot C} \quad (7)$$

Equation 6 may be solved for P to permit calculation of FTE physicians required to service a given number of patients (N). $N \cdot D \left(\sum_{j=1}^n a_j \cdot t_j \right)$

$$P = \frac{N \cdot D \left(\sum_{j=1}^n a_j \cdot t_j \right)}{s \cdot C} \quad (8)$$

The same expression with the expected number of encounters (E) as an input obviates the requirement for N and may be written:

$$P = \frac{E \left(\sum_{j=1}^n a_j \cdot t_j \right)}{s \cdot C} \quad (9)$$

This latter equation is important in that the value of E is easier to obtain or estimate than is N. The number of appointments or encounters for a future time might be arrived at through forecasting. The penalty

attached to forecasting demand based on past demand is its insensitivity to population changes. Forecasting demand for medical services has been the subject of extensive research.²

Due to the deterministic nature of the model, dynamic effects are not considered. The model can quantify effects of changing policy variables that may aid in planning staffing or changing the operating schedule. An examination of the dynamic effects of say encounters that are longer or shorter than planned appointments, requires simulation and is not accomplished in this study.

² Griffith, J.R., Quantitative Techniques for Hospital Planning and Control, Chapters III & IV, Heath and Co., 1972.

IV. ANALYSIS AND SENSITIVITY OF THE MODELS

A. EMPIRICAL BASIS FOR MODEL PARAMETERS

Data collected for this study served as a basis for parameters in the model. Table 13 displays the values.

TABLE 13
VALUES OF THE MODEL PARAMETERS

Parameter	1	2	3	4	5
a_i	.057	.370	.379	.147	.049
t_i	20	10	20	15	20

The fraction a_i is the ratio of encounters for treatment i to all encounters for all treatments i.e. E_i/E . The scheduled length of appointment or service time t_i was assigned by the clinic. Equation (1) provided the values for mean demands for type of treatment (d_i).

B. PATIENTS DEMANDS TO BE SATISFIED

The model was applied to determine the effect of changing parameters set by policy on the number of appointments or encounters. It was assumed that all treatments have inherently different service times. However, there

exists an overall service time $\hat{t} = \sum_{j=1}^n a_j \cdot t_j$ that

represents the grand average of all service times for all treatments. Setting C at 1740 and 3480 minutes per week, P at one FTE physician, and allowing $\hat{t}$ to vary incrementally from 5 to 25 minutes in equation (5), Figure 1 was prepared. Doubling clinic operating time increases number of encounters. As $\hat{t}$ increases, the number of encounters decreases dramatically at low values and then levels off.

In table 14 numbers of patient encounters per week are indicated under a variety of conditions. Low (L), probable (P) and high (H) values are assigned to C, the clinic operating time and to t_{OB} , t_{GYN} the scheduled service times for OB and GYN patients respectively. In this table the different types of service were reduced from five to two for clarity of presentation. Each of the times represent the overall treatment times for all OB treatments and all GYN treatments. Planning estimates and empirical data indicate the demand for OB services to be approximately 42 percent and GYN 58 percent of the total. The low, probable, and high values for FTE physicians was set at 5.0, 5.3 and 6.0 man weeks respectively. Figure 2 plots encounters versus FTE physicians taken from columns of Table 14 where t_{OB} is

FIGURE 1
 ENCOUNTERS PER FTE PHYSICIANS vs
 AVERAGE SERVICE TIME ($\hat{t}$)

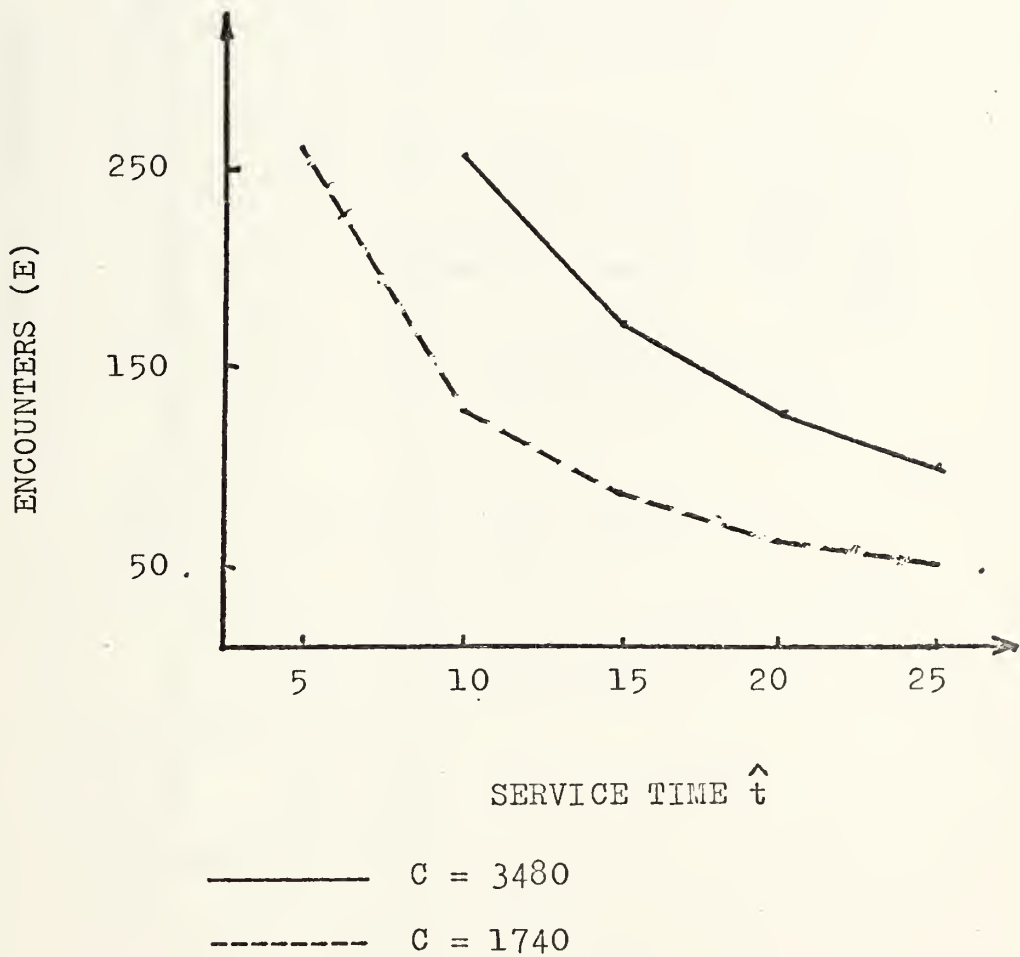
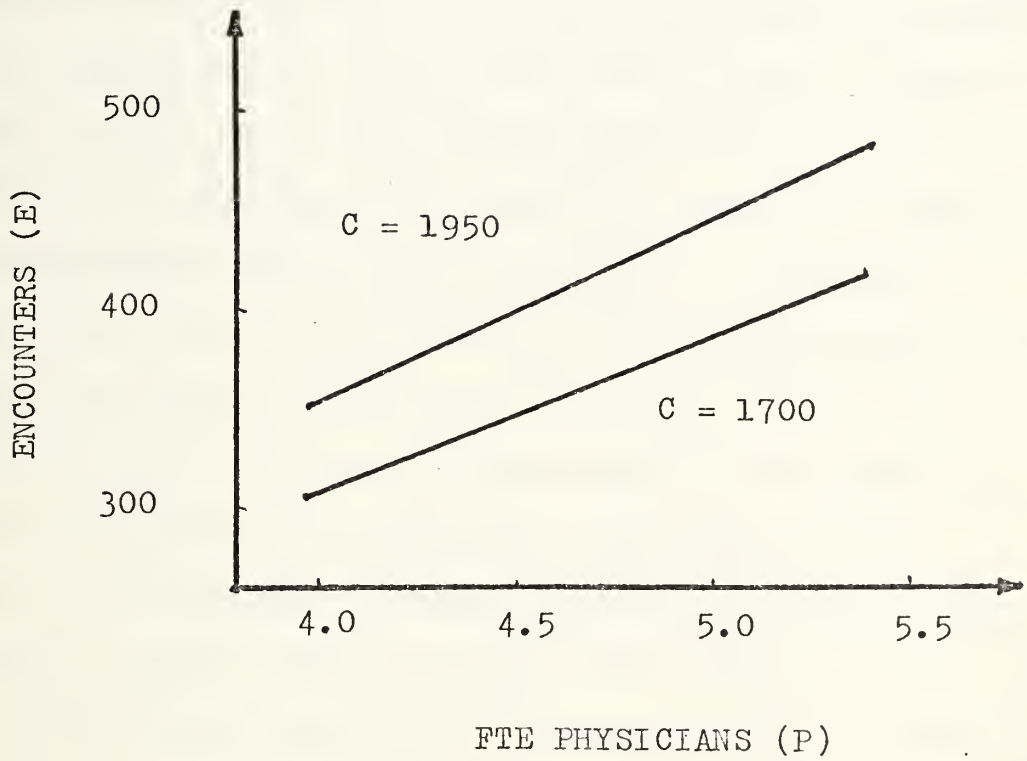


TABLE 14
ENCOUNTERS PER WEEK

		L			P			H		
C		1700			1800			1950		
PTE Physicans	t _{OB} t _{GYN}	L	P	H	L	P	H	L	P	H
		10	14	16	10	14	16	10	14	16
		18	20	22	18	20	22	18	20	22
35 L 5.0 P 5.3 H 6.0		433	388	325	457	410	344	496	444	373
		459	411	344	486	435	364	526	471	395
		519	465	390	549	492	413	596	533	447

$$E = \frac{s \cdot P \cdot C}{\sum_{j=1}^n a_j \cdot t_j}$$

FIGURE 2
ENCOUNTERS PER WEEK
vs FTE PHYSICIANS



equal to 14 minutes and t_{GYN} is equal to 20 minutes. The number of encounters increases as clinic operating time and FTE physicians increase. Comparison of the columns of Table 14 indicates that as service time increases the number of encounters during the week decreases.

Over a period of 52 weeks, the hospital clinic experienced a low of 415, a mean of 507, and a high of 623 clinic visits per week for all treatment.³ Many of the values in Table 14 fall between the high and low values indicating that the parameters used in the model are representative of the real world clinic. Using the above values for clinic visits, the number of FTE physicians (P) required to service a number of outpatients are calculated using equation 8 and are displayed in Table 15. For a given number of encounters and service times the number of FTE physicians decreased as the length of the work week is increased. For a given work week and number of outpatients, the number of FTE physicians required increased as service time increased. Figure 3 graphs selected values from Tables 14 and 15 to demonstrate the decrease in encounters due to increasing overall service time $\hat{t}$ for a fixed endowment of 4.5 and 2.0 FTE physicians.

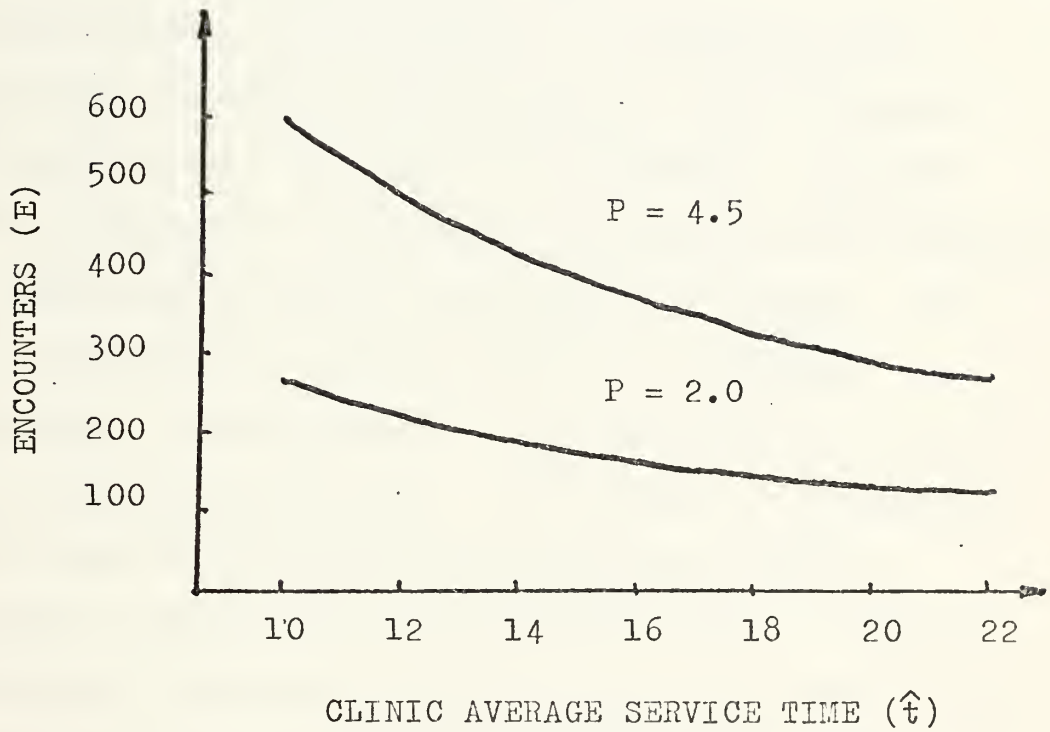
³ Fort Ord Medical Department Activity Review and Analysis 4th Quarter FY 1975, U.S. Army MEDDAC, Fort Ord, Ca., p.5-1.

TABLE 15
 THE PHYSICIANS REQUIRED

Number of Encounters Per Week	1700				1800				1950			
	10		14		16		10		14		10	
	t _{OB}	t _{GYN}	t _{OB}	t _{GYN}	t _{OB}	t _{GYN}	t _{OB}	t _{GYN}	t _{OB}	t _{GYN}	t _{OB}	t _{GYN}
415	4.8	5.4	5.6	4.5	5.1	5.3	4.2	4.7	4.9	4.7	4.2	4.9
507	5.9	6.5	6.9	5.5	6.2	6.5	5.1	5.7	6.0	5.7	5.1	6.0
623	7.2	8.0	8.5	6.8	7.6	8.0	6.3	7.0	7.4	7.0	6.3	7.4

$$P = \frac{E \cdot \sum_{j=1}^n a_i \cdot t_i}{C \cdot S}$$

FIGURE 3
ENCOUNTERS vs SERVICE TIME
FOR VARIOUS FTE PHYSICIANS



In the upper curve, for 4.5 FTE physicians, the number of encounters drops dramatically as $\hat{t}$ increases from 10 to 14 minutes. The curve for two FTE physicians is less steep than the first and flattens quickly.

In Figure 4 is plotted the number of FTE physicians required to treat outpatients at various rates. The value of C is held constant at 1800 minutes per week. Curves for two values of E are displayed. The slope of the curve is greater at higher values of E than for lower values of encounters per week.

While numbers of appointments or encounters are sensitive to treatment time in general, the sensitivity is not uniform over all types of treatments. Patients receiving treatment 3 represent 40 percent of all patients, those receiving treatment 5 represent 5.2 percent. The effect of decreasing service time for a treatment representing a large percent of the work load can dramatically increase appointments. The payoff for decreasing service time for treatments representing a smaller percentage of the work load is less dramatic. Table 16 contrasts the additional encounters that are generated by decreasing service time for two different treatments.

For service type (3) decreasing the average service time from 20 minutes to 18 minutes yields 22 additional appointment slots of that type. For service type (5) the

FIGURE 4

FTE PHYSICIANS VS AVERAGE SERVICE TIME ($\hat{t}$)

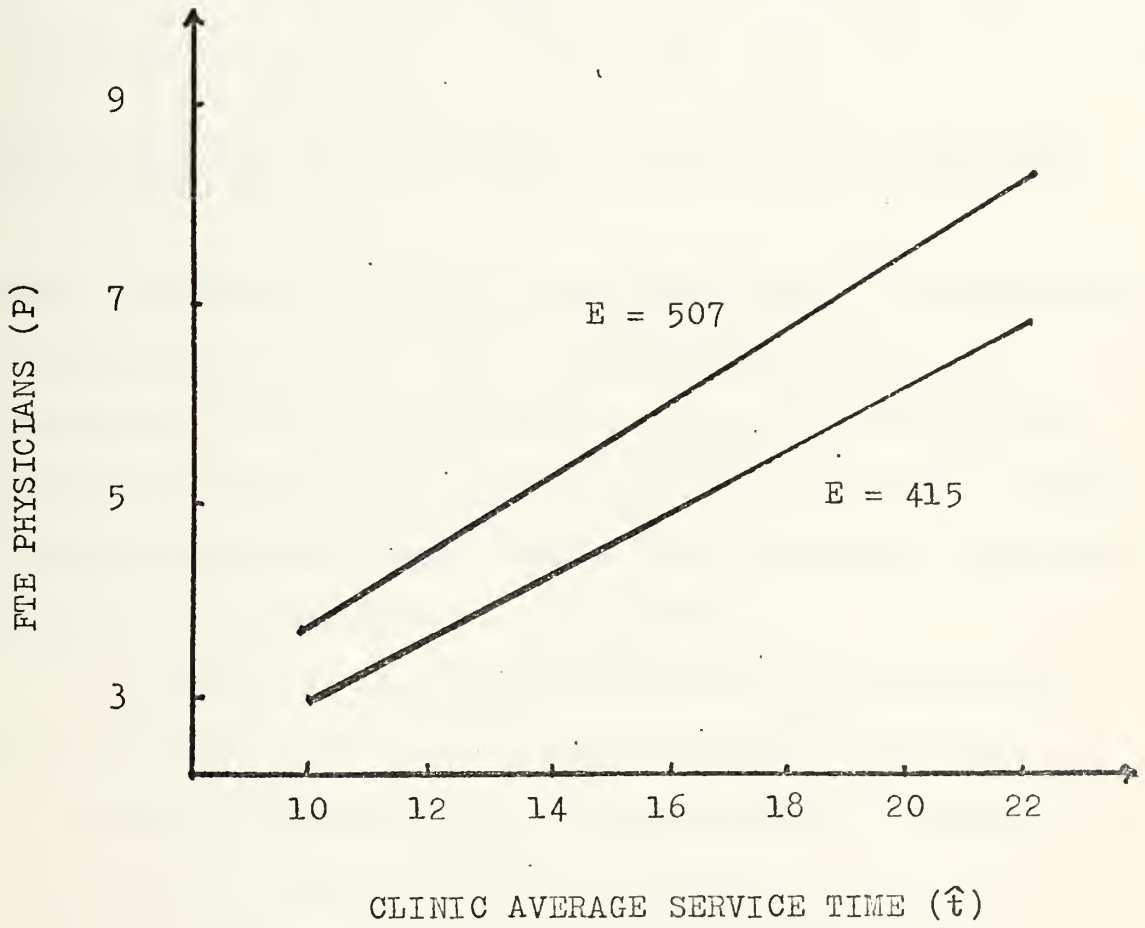


TABLE 16

ADDITIONAL APPOINTMENT SLOTS GENERATED PER WEEK

BY DECREASING AVERAGE SERVICE TIME

Service Type [*]	Service Time (Minutes/Encounter)						
	24	22	20	18	16	14	12
(3)Appointments	165	180	198	220	247	283	330
Increase		15	18	22	27	36	47
(5)Appointments	18	20	22	24	27	31	36
Increase		2	2	2	3	4	5

*Service type (3) is GYN clinic, type (5) is Postpartum, Post operative.

same reduction in service time yields only two additional appointments of that type. This provides numerical specificity to the intuitively obvious conclusion that efforts to reduce the service time for that service which has the largest numerical demand permit the most significant increase in appointments or encounters.

In Table 17, number of patients per FTE physician are indicated. As clinic operating time C increases the number of patients per FTE physician (N) increases linearly. As service time t_i increases N decreases linearly. Figure 5 indicates that as demand rate D increases N decreases but nonlinearly.

C. CONSTRAINTS ON THE MODELS

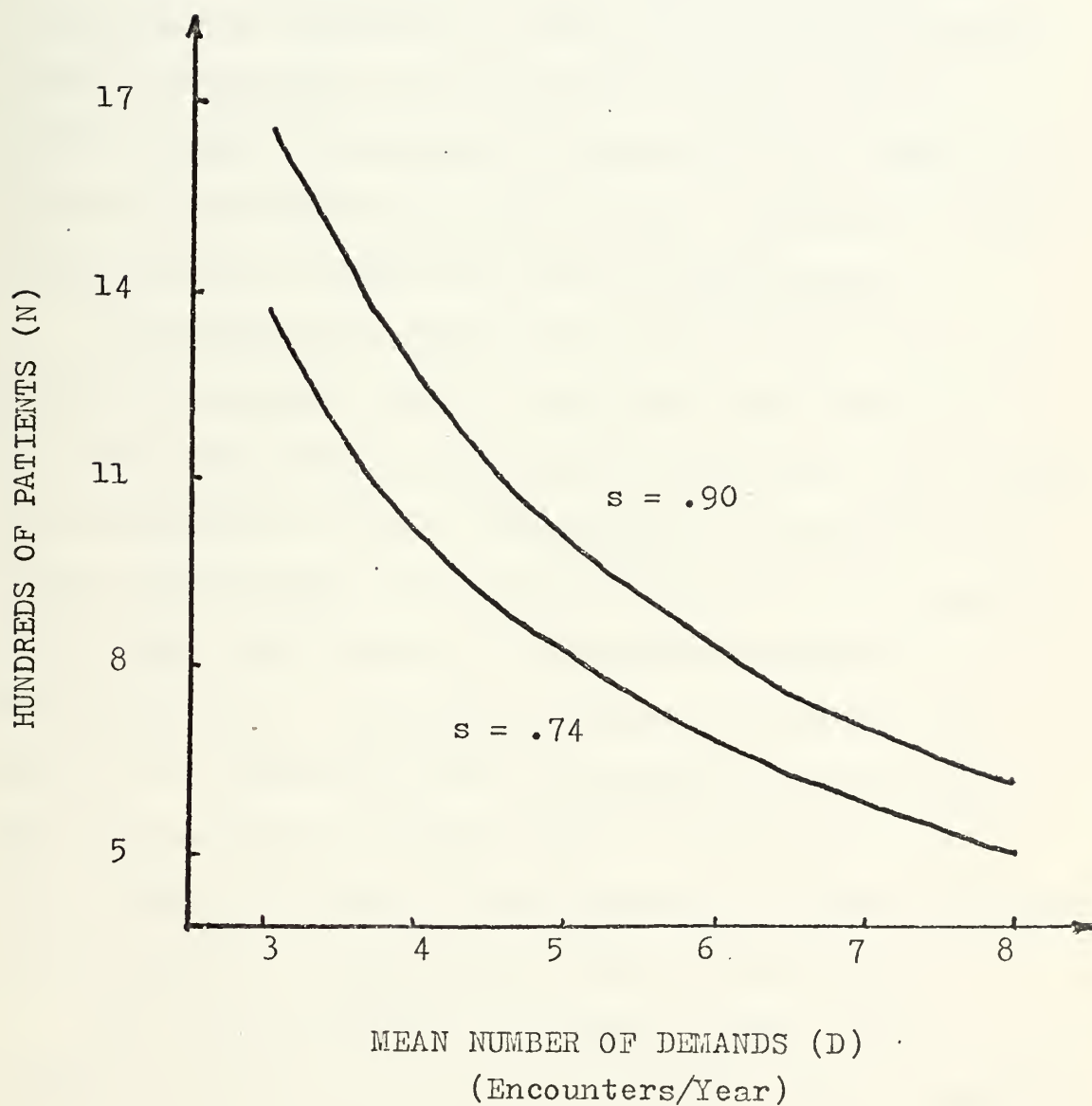
The proposed models do not include resources other than physicians and clinic time. In practice medical

TABLE 17
NUMBER OF PATIENTS PER FTE PHYSICIAN
FOR VARIOUS CONDITIONS

C		1700			1800			1950		
D	t	15	17	19	15	17	19	15	17	19
3.7/52		1183	1044	934	1252	1105	989	1357	1197	1071
5.2/52		842	743	664	891	786	703	965	852	762
5.9/52		742	654	586	785	693	620	851	751	672

$$N = \frac{P.C.s}{D.\hat{t}}$$

FIGURE 5
PATIENTS PER FTE PHYSICIAN vs.
MEAN NO. OF DEMANDS PER YEAR (D)



services delivery personnel would include doctors, nurse clinicians, registered nurses, practical nurses, medical assistants, and laboratory technicians. Physical resources include expendable supplies, equipment, examination rooms and doctor's offices. Each of these resources contribute to the output of the clinic and have the potential to constrain the type and frequency of treatment or the number of outpatients treated. It is possible that other medical personnel can be substituted for or augment available physicians. However, to model that problem is beyond the scope of this study.

The physical layout of the clinic studied did not constrain current output. The layout can accommodate six FTE physicians working from an office and two adjoining examination rooms. When availability permitted and work load demanded, one physician worked in one examination room. This permits a theoretical maximum of 12 FTE physicians. Changing the mode of operation from two to one examining rooms per physician would change the rate at which patients would be processed. It is not likely the number of encounters is a linear function of the number of examination rooms per physician.

The policy variable of length of unit clinic operating period C is subject to change. Use of shorter or staggered lunch breaks would generate a larger C without changing open and close times. If demand required,

a one and a half or two shift operation might be instituted. The five day work week could be increased to six.

The consumption of consumable supplies and equipment is a function of number of outpatients treated. These resources are subject to budget limitation but there was no evidence these resources constrained output.

The responsibility of military clinic physicians for inpatient care and administrative requirements outside the clinic constrained their availability to the clinic. As inpatient and administrative requirements increased, the number of appointments for outpatients decreased proportionately.

V. CONCLUSIONS

As presented this model has the capability to provide the hospital manager with a quantitative basis for a decision concerning the physician staffing of appointment clinics. Having arrived at a figure for FTE physician staffing, the additional staffing for inpatient care and administrative functions would need to be determined independently.

The model is sensitive to the numbers of demands for various types of treatment. Developing better estimates of the expected number of clinic visits by type of treatment could be accomplished. Current and past data of this type has not been presented in this study but is undoubtedly available.

In the clinic studied the number of appointments scheduled was limited by physician availability. No record of unfilled demands for service was kept nor was the population being served known. Therefore, clinic data on visit rates by type of treatment were used only to estimate the relative demand for each type of service. Total incidence rates for outpatient care were estimated from other literature. Local incidence rates might vary considerably from the representative values used.

Until hospital service area population is determined and incidence rates applied, parameters must be estimated for the model. Were those statistics available, the model might be used to change staffing in advance of the changed demand rather than in reaction to the change. Knowledge of population statistics also has implication for frequency of issue of non-availability statements use of CHAMPUS, and quality of health care.

Quality health care for clinic visits might be measured in terms of patient-physician encounter time. After establishing standards expressed as values of t_i several things might occur. First, as demands for service exceed capability of physician resources, patients are turned away or not granted appointments, or the standard is consistently not met. Second, during periods of slack demand standards will be set higher on an ad-hoc basis or physicians will be under-utilized in the out-patient care function. The proposed model can assist management in establishing standards and quantifying the extent to which demand exceeds resources, or amount of unfilled patient demand.

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